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USE OF THE SLIDE RULE IN THE COMPUTATION OF ROCK ANALYSES

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Certain phases of petrographic and metamorphic work require the conversion of rock analyses into the corresponding approximate mineralogical compositions. By ordinary methods of calculation this may be rather prolonged and call for a considerable expenditure of time and energy. Exact conversion is, of course, impossible, especially without any preliminary data as to the minerals actually present, and, in the case of such variables as the biotites, amphiboles, and pyroxenes¹ their chemical composition itself should be determined also. Nevertheless the results attainable are of sufficient value to justify the procedure.

Various methods have been suggested, each possessing more or less merit and marking some advance in this direction. The use of molecular ratios has been very general and has been described by Kemp,² Cross,³ and Osann.⁴ Harker⁵ calculated decimal tables for the different minerals which very materially assist in converting oxide values into the corresponding mineral values, but which are not adapted to the reverse process which in some cases is of equal importance. Mead⁶ devised a set of graphic tables, one for each mineral, by means of which the value of any radicle in a mineral might be converted into the corresponding value of any other radicle

¹ Cross, Iddings, Pirsson, and Washington, *Quantitative Classification of Igneous Rocks*, 1903, p. 145.

² J. F. Kemp, "The Recalculation of the Chemical Analyses of Rocks," *School of Mines Quarterly*, XXII (1900-1901), 75.

³ Cross, Iddings, *et. al.*, *op. cit.*, Part III, "Methods of Calculation."

⁴ A. Osann, *Beiträge zur chemischen Petrographie*, I. Teil. "Molekular-Quotienten zur Berechnung von Gesteinsanalysen," Stuttgart, 1903.

⁵ A. Harker, private publication, Cambridge University Press, 1910.

⁶ W. J. Mead, "Some Geological Short-Cuts," *Economic Geology*, VII, No. 2 (March, 1912), 136.

in that same mineral or to the total mineral value. Conversely, the value of any radicle could be determined from the total mineral value. This marked a decided step in advance, but as a complete table is necessary for each mineral the disadvantages are obvious.

Later in the same article¹ Mead describes a "geologist's slide rule," which is a much more efficient method of conversion, and which has certainly merited a wider consideration than it has apparently received. He has devised a rule for ordinary rock minerals and another one for ore minerals, comprising a total of nearly 100 minerals, whereby very rapid conversions and comparisons are possible, either from constituent to mineral or the reverse. The rules are of white celluloid, about ten inches in diameter and are exceedingly simple to manipulate. In using these rules certain features became apparent to the writer: (1) a rule is good only for the minerals printed thereon; (2) ordinary slide-rule computations are impossible on the logarithmic scale of the rule; (3) the rule is too large for ordinary pocket use and hence of limited value in the field. These statements are not intended to detract in any way from the value of the "geologist's slide rule," but led the writer to consider a way to broaden this excellent application of the logarithmic scale to geologic work.

In a recent publication Lindgren² gives a summary of the various methods of recalculation. The scheme most favored "consists of a co-ordinate system in which the abscissas represent the distance from the vein which may be taken as the origin of the acting solutions, and the ordinates represent the molecular ratios multiplied by 100, except for silica, for which the scale must be reduced to bring the diagram within convenient compass." This method is excellent for just such cases as cited,³ but a diagram so constructed is limited to one definite zone or locality and does not have the range of broad comparisons and generalizations inherent in the straight line diagram.

In the conversions and comparisons of chemical analyses referred to, considerable multiplication and division are necessary

¹ *Ibid.*, p. 139.

² Waldemar Lindgren, *Mineral Deposits*, 1913. Chap. xxx.

³ F. L. Ransome, *U.S. Geol. Survey Professional Paper* 75.

in addition to that obviated by the "geologist's slide rule." For this work slide-rule accuracy is sufficient. In extended studies of this nature the use of the rule may save from 50 to 90 per cent of the time required for such calculations. Hence, if these conversions could be simply accomplished on an ordinary slide rule, considerable time and energy would be saved and the rule might then attain the same merited popularity with geologists that it has already won in engineering lines. At the same time its compact nature lends itself more readily to field use.

For these reasons the writer submits the accompanying tables (Tables I and II) of mineral percentage compositions, with a method of use applicable to any ordinary slide rule, which he trusts may meet the foregoing conditions successfully. In addition, conversion into molecular values by means of tables such as given by Osann¹ can be so much more quickly accomplished on a slide rule than by ordinary arithmetical processes.

	I*	II†
SiO ₂	76.87	48.45
TiO ₂	0.07	0.53
Al ₂ O ₃	13.10	18.47
Fe ₂ O ₃ }.....	1.05	{ 4.81
FeO }.....		{ 3.96
MnO.....	0.01	0.06
MgO.....	0.06	3.50
CaO.....	0.45	7.38
Na ₂ O.....	3.55	4.58
K ₂ O.....	4.83	7.78
P ₂ O ₅	0.01	0.48

* R. A. Daly, *Igneous Rocks and Their Origin*, 1914, p. 34, No. 97 (alaskite).

† *Ibid.*, p. 32, No. 90 (leucitite).

These tables contain two sets of minerals, one the more common of the rock-forming variety, the other the more important ore minerals. Precise mineral composition is, of course, only theoretically attained, but the formulae given are taken from standard texts² and represent generally accepted values. An

¹ A. Osann, *Beiträge zur Chemischen Petrographie*, I. Teil, "Molekular-Quotienten zur Berechnung von Gesteinsanalysen," Stuttgart, 1913.

² E. S. Dana, *Textbook of Mineralogy*; Moses and Parsons, *Mineralogy, Crystallography and Blowpipe Analysis*; F. W. Clarke, "Data of Geochemistry," *U.S. Geological Survey Bulletin* 491; Albert Johannsen, *Determination of Rock-forming Minerals in Thin Sections*.

average value for specific gravity is given instead of the range usually stated, as this average is accurate enough for such computations, and in fact is more accurate than the reconstructed analyses. This is due to the fact that the rocks of unlike mineral composition may have identical chemical composition, and also due to the range in chemical composition of such minerals as the biotites, amphiboles, pyroxenes, garnets, spinels, etc. The use of the tables may be explained most easily by taking two rock analyses and performing two conversions such as commonly confront the petrographer.

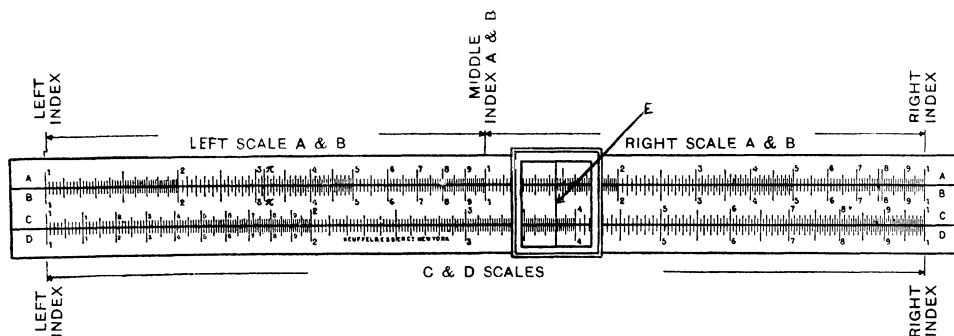
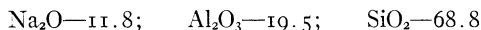


FIG. 1

The ordinary slide rule (see Fig. 1) has four graduated logarithmic scales, two on the immovable portion and two on the slide. For convenience these are referred to as "A," "B," "C," and "D," beginning with the upper one and reading downward. For brevity's sake the vertical line on the glass slide will be termed "E." A and B are duplicates, as are C and D. In using the mineralogical tables the scales C and D only are needed. First we shall proceed to reconstruct albite in Analysis I. The chemical analysis shows the presence of 3.55 per cent Na_2O . In Table I the percentage composition of albite is found to be

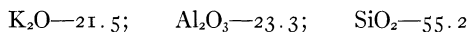


Set "E" on 118 on "D" and move "C" until 355 on this scale is under "E." Then if the corresponding amount of albite is desired.

move "E" to the left index on "D." The reading on "C" under "E" is 30.1, which means that 30.1 per cent of albite is equivalent to 3.55 per cent of Na_2O . Similarly, to find the amount of Al_2O_3 needed to combine with 3.55 per cent Na_2O in the albite molecule move "E" to 195 on "D." This will then cross "C" at 587, which indicates a requirement of 5.87 per cent of Al_2O_3 . The sliding portion of the rule (carrying scales "B" and "C") has been set but once for both these readings. Now suppose that the SiO_2 value in albite corresponding to 3.55 per cent Na_2O is desired. In the table the SiO_2 percentage is 68.8. This value on "D" is not under "C" at all in the present setting. The next operation corresponds merely to doubling the length of the scale on "C." Place "E" on the right index of "C" and then move "C" to the right until the left index of "C" is under "E." Then move "E" to 688 on "D" and it is found to cross "C" at 20.7 which is the SiO_2 value required. A check on the correctness of these values thus obtained is to total the constituents and compare with the total obtained on "C."

Total on "C"	Separate Percentages
Albite—30.1 per cent	Na_2O —3.55 per cent
	Al_2O_3 —5.87 " "
	SiO_2 —20.7 " "
	Total—30.12 per cent

Now suppose we consider the potash in Analysis II which probably was present as leucite (7.78 per cent). Table I shows the composition of leucite as follows:

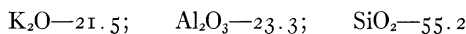


Set "E" on 215 on "D" and move the slide so that 778 on "C" is under "E," or is opposite 215 on "D." Move "E" to the left index on "D" and it is found to cross "C" at 36.19, which is the percentage of leucite present. In order to get the corresponding value of Al_2O_3 move "E" to 233 on "D." In this position it crosses "C" at 8.43, the percentage of Al_2O_3 . The silica value, 55.2 on "D," again falls under the blank space in the rule, so set "E" on the right index of "C," move the slide to the right so that the left

index of "C" is under "E" and then set "E" on 552 on "D." In this position it crosses "C" at 19.98.

Total on "C"	Separate Percentages
Leucite—36.19 per cent	K ₂ O—7.78 per cent
	Al ₂ O ₃ —8.43 " "
	SiO ₂ —19.98 " "
	Total—36.19 per cent

The reverse operation, or conversion of minerals to their constituent oxides, will now be described. Suppose we take the case just cited. A rock contains 36.19 per cent leucite. What are the corresponding values of K₂O, Al₂O₃, and SiO₂? The percentage composition of leucite is



Set "E" over an index on "D," and since there is a choice of two such positions (one at each end of the scale) suppose the right index of "D" is chosen. Then move the slide so that the leucite percentage, 36.19 on "C," is under "E." It will be noted that of the three oxide values—21.5, 23.3, 55.2—only that of silica can be found on "D" under the slide in its present position. Hence set "E" on 552 on "D" and it will be found to cross "C" at 19.98, the percentage value of SiO₂. Then shift the slide so that 36.19 on "C" is opposite the left index on "D." Set "E" on 215 on "D" and it will cross "C" at 7.78, which is the potash value in the leucite percentage. Move "E" to 233 on "D" and it will cross "C" at 8.43, which is the Al₂O₃ value desired.

This explanation covers any ordinary case, including both the synthetical and the analytical processes. If the following point is borne in mind there should be no confusion. In the method as outlined, all percentage values from the table were read on "D," whereas all analytical values and their equivalents were read on "C." The opposite way is equally feasible, but if one way is always followed there is little excuse for confusion. Similarly, all these operations can be performed on scales "A" and "B," but the divisions are smaller and not so easily read.

TABLE I

ROCK MINERALS

Actinolite:	3.1—CaMg ₃ FeSi ₈ O ₂₂ :CaO—12.5; MgO—17.9; FeO—16.0; SiO ₂ —53.6
Aegirite:	3.55—NaFeSi ₂ O ₆ :Na ₂ O—13.4; Fe ₂ O ₃ —34.5; SiO ₂ —52.1
Albite:	2.63—NaAlSi ₃ O ₈ :Na ₂ O—11.8; Al ₂ O ₃ —19.4; SiO ₂ —68.8
Almandine:	4.05—Fe ₃ Al ₂ Si ₅ O ₁₂ :FeO—43.2; Al ₂ O ₃ —20.5; SiO ₂ —36.3
Alunite:	2.66—KAl ₃ O ₆ H ₉ S ₂ O ₆ :K ₂ O—11.4; Al ₂ O ₃ —37.0; SO ₃ —38.6; H ₂ O—13.0
Analcite:	2.25—NaAlSi ₃ O ₆ H ₂ O:Na ₂ O—14.0; Al ₂ O ₃ —23.2; SiO ₂ —54.6; H ₂ O—8.2
Andalusite:	3.18—Al ₂ SiO ₅ :Al ₂ O ₃ —62.9; SiO ₂ —37.1
Andesine:	2.68—Ab ₃ An ₂ :Na ₂ O—6.9; CaO—8.3; Al ₂ O ₃ —26.6; SiO ₂ —58.2
Andradite:	3.85—Ca ₃ Fe ₂ Si ₃ O ₁₂ :CaO—33.0; Fe ₂ O ₃ —31.5; SiO ₂ —35.5
Anhydrite:	2.94—CaSO ₄ :CaO—41.2; SO ₃ —58.8
Anorthite:	2.75—CaAl ₂ Si ₂ O ₈ :CaO—20.1; Al ₂ O ₃ —36.7; SiO ₂ —43.2
Apatite:	3.20—Ca ₄ (CaF) ₃ P ₃ O ₁₂ :CaO—55.5; P ₂ O ₅ —42.3; F—3.8
Augite:	3.31:CaO—20.9; MgO—12.6; FeO—6.9; Fe ₂ O ₃ —4.6; Al ₂ O ₃ —7.4; SiO ₂ —47.6
Barite:	4.45—BaSO ₄ :BaO—65.7; SO ₃ —34.3
Bauxite:	2.48—Al ₂ O ₃ ·2H ₂ O:Al ₂ O ₃ —73.9; H ₂ O—26.1
Biotite:	2.95:K ₂ O—11.2; (Mg, Fe)O—19.2; Al ₂ O ₃ —24.4; SiO ₂ —43.1; H ₂ O—2.1
Calcite:	2.72—CaCO ₃ :CaO—56; CO ₂ —44
Chlorite (Penninite):	2.72:MgO—19.5; FeO—23.2; Al ₂ O ₃ —16.5; SiO ₂ —29.2; H ₂ O—11.6
Diopside:	3.33—CaMgSi ₂ O ₆ :CaO—25.8; MgO—18.6; SiO ₂ —55.6
Dolomite:	2.84—CaMgC ₂ O ₆ :CaO—30.4; MgO—21.7; CO ₂ —47.9
Enstatite:	3.17—MgSiO ₃ :MgO—40; SiO ₂ —60
Epidote (Pistacite):	3.38—Ca ₂ (Al, Fe) ₃ HSi ₃ O ₁₃ :CaO—23.5; Al ₂ O ₃ —24.1; Fe ₂ O ₃ —12.6; SiO ₂ —37.9; H ₂ O—1.9
Fayalite:	4.14—Fe ₂ SiO ₄ :FeO—70.6; SiO ₂ —29.4
Fluorite:	3.13—CaF ₂ :Ca—51.1; F—48.9
Forsterite:	3.25—Mg ₂ SiO ₄ :MgO—57.1; SiO ₂ —42.9
Gibbsite:	2.36—Al(OH) ₃ :Al ₂ O ₃ —65.4; H ₂ O—34.6
Grossularite:	3.57—Ca ₃ Al ₂ Si ₃ O ₁₂ :CaO—37.3; Al ₂ O ₃ —22.7; SiO ₂ —40.0
Gypsum:	2.32—CaSO ₄ ·2H ₂ O:CaO—32.6; SO ₃ —46.6; H ₂ O—20.9
Halloysite:	2.1—Al ₂ Si ₂ O ₇ ·3H ₂ O:Al ₂ O ₃ —36.9; SiO ₂ —43.5; H ₂ O—19.6
Hedenbergite:	3.6—CaFeSi ₂ O ₆ :CaO—22.2; FeO—29.4; SiO ₂ —48.4
Hornblende:	3.24:CaO—5.8; MgO—8.3; FeO—22.1; Fe ₂ O ₃ —16.3; Al ₂ O ₃ —10.5; SiO ₂ —37.0
Hyperssthene:	3.45—(Mg, Fe)SiO ₃ :MgO—17.3; FeO—30.9; SiO ₂ —51.8
Kaolinite:	2.62—Al ₂ Si ₂ O ₇ ·2H ₂ O:Al ₂ O ₃ —39.5; SiO ₂ —46.5; H ₂ O—14.0
Labradorite:	2.71—Ab ₂ An ₃ :Na ₂ O—4.6; CaO—12.3; Al ₂ O ₃ —30.0; SiO ₂ —53.1
Leucite:	2.48—KAlSi ₂ O ₆ :K ₂ O—21.5; Al ₂ O ₃ —23.3; SiO ₂ —55.2
Magnesite:	3.04—MgCO ₃ :MgO—47.6; CO ₂ —52.4
Melilite:	3.0:Na ₂ O—4.3; CaO—31.3; MgO—8.4; Fe ₂ O ₃ —11.2; Al ₂ O ₃ —7.1; SiO ₂ —37.7
Muscovite:	2.87—H ₃ KAl ₃ Si ₃ O ₁₂ :K ₂ O—11.8; Al ₂ O ₃ —38.5; SiO ₂ —45.2; H ₂ O—4.5
Nephelite:	2.6—K ₂ Na ₆ Al ₈ Si ₆ O ₃₄ :K ₂ O—7.7; Na ₂ O—15.1; Al ₂ O ₃ —33.2; SiO ₂ —44.0
Oligoclase:	2.66—Ab ₃ An ₁ :Na ₂ O—8.8; CaO—5.2; Al ₂ O ₃ —23.9; SiO ₂ —62.1
Orthoclase:	2.56—KAlSi ₃ O ₈ :K ₂ O—16.9; Al ₂ O ₃ —18.4; SiO ₂ —64.7
Serpentine:	2.56—H ₂ Mg ₃ Si ₂ O ₉ :MgO—43.0; SiO ₂ —44.1; H ₂ O—12.9
Staurolite:	3.70—HFeAl ₅ Si ₄ O ₁₃ :FeO—15.8; Al ₂ O ₃ —55.9; SiO ₂ —26.3; H ₂ O—2.0
Talc:	2.73—H ₂ Mg ₃ Si ₂ O ₉ :MgO—31.7; SiO ₂ —63.5; H ₂ O—4.8
Titanite:	3.52—CaTiSiO ₅ :CaO—28.6; TiO ₂ —40.8; SiO ₂ —51.7
Wollastonite:	2.85—CaSiO ₃ :CaO—48.3; SiO ₂ —51.7
Zircon:	4.69—ZrSiO ₄ :ZrO ₂ —67.2; SiO ₂ —32.8
Zoisite:	3.31—HCa ₂ Al ₃ Si ₃ O ₁₃ :CaO—24.6; Al ₂ O ₃ —33.7; SiO ₂ —39.7; H ₂ O—2.0
Oxides	{ Al ₂ O ₃ : Al—53.03; O—46.97
	{ BaO: Ba—89.58; O—10.42
	{ CaO: Ca—71.47; O—28.53
	{ CO ₂ : C—27.27; O—72.73
	{ Cr ₂ O ₃ : Cr—68.42; O—31.58
	{ CuO: Cu—79.51; O—20.49
	{ FeO: Fe—76.34; O—23.66
	{ K ₂ O: K—83.02; O—16.98
	{ MgO: Mg—60.32; O—39.68
	{ MnO: Mn—77.44; O—22.56
	{ Na ₂ O: Na—74.19; O—25.81
	{ PbO: Pb—92.83; O—7.17
	{ P ₂ O ₅ : P—43.69; O—56.31
	{ SO ₃ : S—40.05; O—59.95

TABLE II

ORE MINERALS

Iron	Iron	Arsenopyrite: 6.05—FeAsS ₂ :Fe—34.3; As—46.0; S—19.7
		Chromite: 4.44—FeCr ₂ O ₄ :FeO—32; Cr ₂ O ₃ —68
		Goethite: 4.2—FeO ₃ .H ₂ O:Fe—62.9; O—27; H ₂ O—10.1
		Hematite: 5.1—Fe ₂ O ₃ :Fe—69.9; O—30.1
		Limonite: 3.8—2Fe ₂ O ₃ .3H ₂ O:Fe—59.8; O—25.7; H ₂ O—14.5
		Magnetite: 5.13—Fe ₃ O ₄ :Fe—72.4; O—27.6 (or FeO—31.0; Fe ₂ O ₃ —69.0)
		Pyrite: 5.03—FeS ₂ :Fe—46.6; S—53.4
		Pyrrhotite: 4.59—Fe ₁₁ S ₁₂ :Fe—61.5; S—38.5
Copper	Copper	Siderite: 3.86—FeCO ₃ :FeO—62.1; CO ₂ —37.9
		Wolframite: 7.28—(Fe, Mn)WO ₄ :WO ₃ —76.5; (Fe, Mn)O—23.5
		Azurite: 3.8—Cu ₃ (CO ₃) ₂ (OH) ₂ :CuO—69.2; CO ₂ —25.6; H ₂ O—5.2
		Bornite: 5.15—Cu ₃ FeS ₄ :Cu—63.3; Fe—11.2; S—25.5
		Chalcanthite: 2.21—CuSO ₄ .5H ₂ O:CuO—31.8; SO ₃ —32.1; H ₂ O—36.1
		Chalcocite: 5.65—Cu ₂ S:Cu—79.8; S—20.2
		Chalcopyrite: 4.2—CuFeS ₂ :Cu—34.5; Fe—30.5; S—35.0
		Chrysocolla: 2.13—CuSiO ₃ .2H ₂ O:CuO—45.2; SiO ₂ —34.3; H ₂ O—20.5
Nickel and Cobalt	Nickel and Cobalt	Covellite: 4.59—CuS:Cu—66.5; S—33.5
		Cuprite: 6.0—Cu ₂ O:Cu—88.8; O—11.2
		Enargite: 4.44—Cu ₃ AsS ₄ :Cu—48.3; As—19.1; S—32.6
		Malachite: 3.97—(CuOH) ₂ CO ₃ :CuO—71.9; CO ₂ —19.9; H ₂ O—8.2
		Tennantite: 4.64—Cu ₈ As ₂ S ₇ :Cu—57.5; As—17.0; S—25.5
		Tetrahedrite: 4.8—Cu ₈ Sb ₂ S ₇ :Cu—52.1; Sb—24.8; S—23.1
		Cobaltite: 6.07—CoAsS:Co—35.5; As—45.2; S—19.3
		Chloanthite: 6.5—NiAs ₂ :Ni—28.1; As—71.9
Manganese	Manganese	Garnierite: 2.55—H ₂ (Ni, Mg)SiO ₄ .xH ₂ O:NiO—27.5; MgO—14.8; SiO ₂ —44.4; H ₂ O—13.3+
		Linnaeite: 4.9—Co ₃ S ₄ :Co—58; S—42
		Millerite: 5.53—NiS:Ni—64.7; S—35.3
		Nickolite: 7.49—NiAs:Ni—43.9; As—56.1
		Pentlandite: 4.75—(Fe, Ni)S ₂ :Ni—32.8; Fe—31.3; S—35.9
		Smaltite: 6.5—(Co, Ni)As ₂ :Co—22.0; Ni—21.9; As—56.1
		Manganite: 4.3—Mn ₂ O ₃ .H ₂ O:Mn—62.4; O—27.3; H ₂ O—10.3
		Psilomelane: 4.2—H ₄ MnO ₆ :H—2.9; Mn—39.5; O—57.6
Silver	Silver	Pyrolusite: 4.78—MnO ₂ .nH ₂ O:Mn—63.2; O—36.8
		Rhodochrosite: 3.5—MnCO ₃ :MnO—61.7; CO ₂ —38.3
		Rhodonite: 3.56—MnSiO ₃ :MnO—54.1; SiO ₂ —45.9
		Argentite: 7.29—Ag ₂ S:Ag—87.1; S—12.9
		Cerargyrite: 5.57—AgCl:Ag—75.3; Cl—24.7
		Dyscrasite: 9.64—Ag ₃ Sb:Ag—72.9; Sb—27.1
		Hessite: 8.41—Ag ₂ Te:Ag—62.9; Te—37.1
		Polybasite: 6.1—(Ag, Cu) ₉ SbS ₆ :Ag—75.6; Sb—9.4; S—15.0
Lead	Lead	Proustite: 5.57—Ag ₃ AsS ₃ :Ag—65.4; As—15.2; S—19.4
		Stibnite: 5.83—Ag ₃ SbS ₃ :Ag—59.9; Sb—22.3; S—17.8
		Stephanite: 6.25—Ag ₃ SbS ₄ :Ag—68.5; Sb—15.2; S—16.3
		Anglesite: 6.25—PbSO ₄ :PbO—73.6; SO ₃ —26.4
		Cerussite: 6.51—PbCO ₃ :PbO—83.5; CO ₂ —16.5
		Galena: 7.5—PbS:Pb—86.6; S—13.4
		Wulfenite: 6.85—PbMoO ₄ :PbO—60.7; MoO ₃ —39.3
Zinc	Zinc	Calamine: 3.45—Zn ₂ SiO ₄ .H ₂ O:ZnO—67.5; SiO ₂ —25.0; H ₂ O—7.5
		Smithsonite: 4.37—ZnCO ₃ :ZnO—64.8; CO ₂ —35.2
		Sphalerite: 4.02—ZnS:Zn—67.0; S—33.0
		Willemite: 4.04—Zn ₂ SiO ₄ :ZnO—73.0; SiO ₂ —27
		Zincite: 5.55—ZnO:Zn—80.3; O—19.7
Antimony	Antimony	Orpiment: 3.48—As ₂ S ₃ :As—61.0; S—39.0
		Realgar: 3.52—As ₂ S ₂ :As—70.1; S—29.9
Arsenic	Arsenic	Stibnite: 4.57—Sb ₂ S ₃ :Sb—71.4; S—28.6
		Ilmenite: 4.7—FeTiO ₃ :Fe—36.8; Ti—31.6; O—31.6
Titanium	Titanium	Rutile: 4.21—TiO ₂ :Ti—61.6; O—38.4 (Fe up to 10)
		Cassiterite: 6.95—SnO ₂ :Sn—78.6; O—21.4
		Cinnabar: 8.1—HgS:Hg—86.2; S—13.8
		Molybdenite: 4.75—MoS ₂ :Mo—60.0; S—40.0

As is true in many other instances, description is much slower and more tedious than manipulation, and the operations herein outlined may be performed easily in a few moments after one is accustomed to the use of the slide rule. To a person unfamiliar with the rule the question of placing the decimal point at once suggests itself. Used with the accompanying tables, the percentage values give all the assistance needed on this point and render the correct interpretation here more facile even than with the "geologist's slide rule." The values obtained should bear the same relations to each other as do the corresponding percentage values in the tables. For other operations the reader unaccustomed to slide-rule use is referred to various directions which are furnished by the manufacturers.

The accompanying tables are believed to be complete enough for most metamorphic, petrographic, and economic uses, but can be augmented to suit special needs. The percentages of a few oxides are included, as these are desirable in many cases. Any arrangement of minerals in such a table can be made to suit individual needs, and such tables mounted separately or back to back and covered with gelatin will be found an excellent form for field use, if such is desired.